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(12) **UK Patent Application** (19) **GB** (11) **2 220 502** (13) **A**

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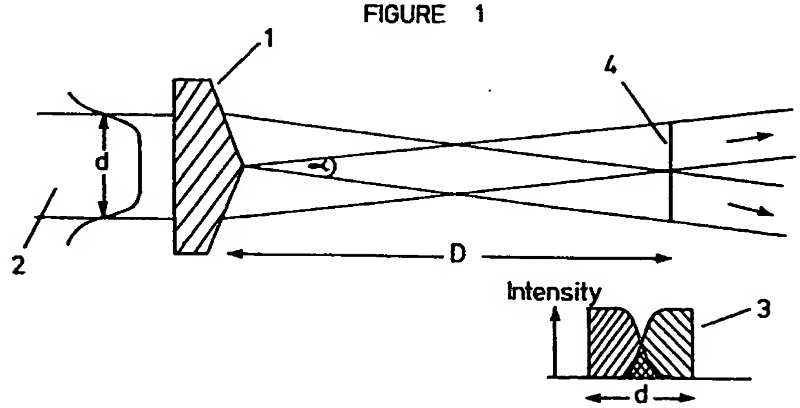
WPI

(54) **Excimer laser beam homogenizer system**

(57) An optical system consisting of one or more transmissive biprisms 1 of fused silica, is used to transform the non uniform output beam from a pulsed UV excimer laser into one with a more uniform energy distribution.

Uniformity in two dimensions is provided by prisms as in (Fig 2) and additionally conversion from rectangular to square beams by lens arrangements as in (Figs 3a, 3b). Colloidal silica spun on antireflection coatings may be provided.

FIGURE 1



The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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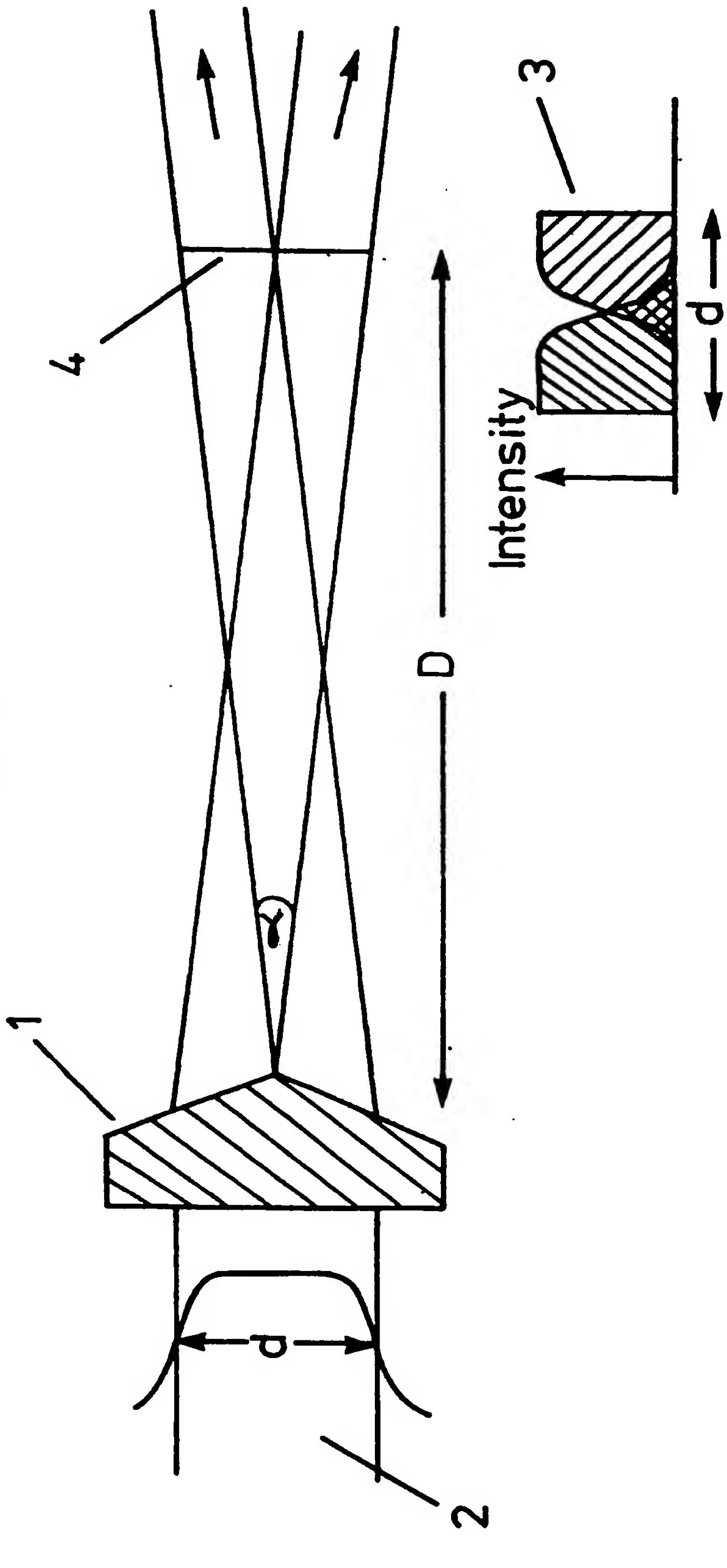
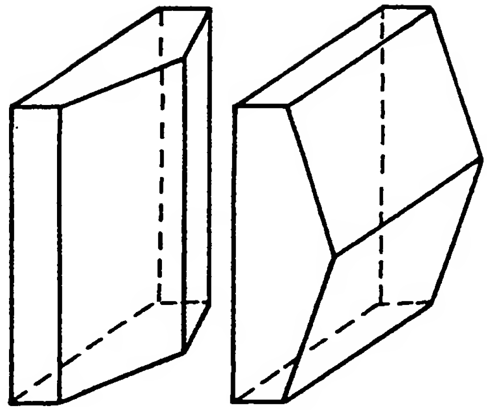


FIGURE 1



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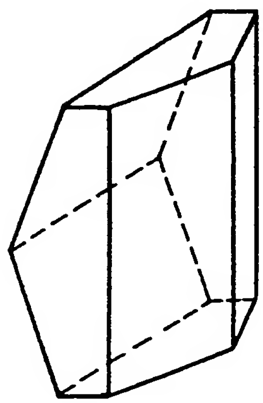

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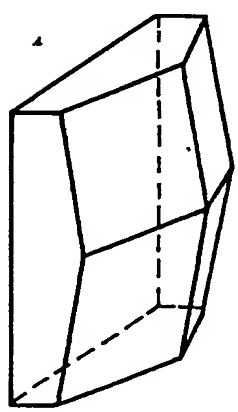

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FIGURE 2

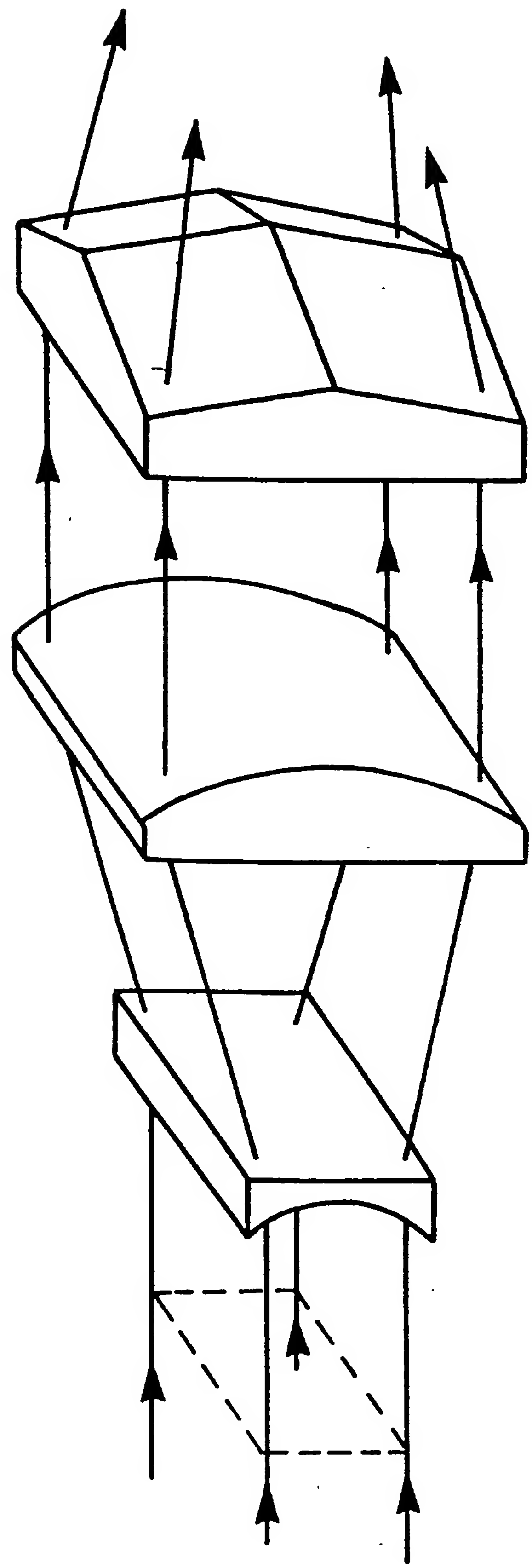

FIGURE 3 (a)

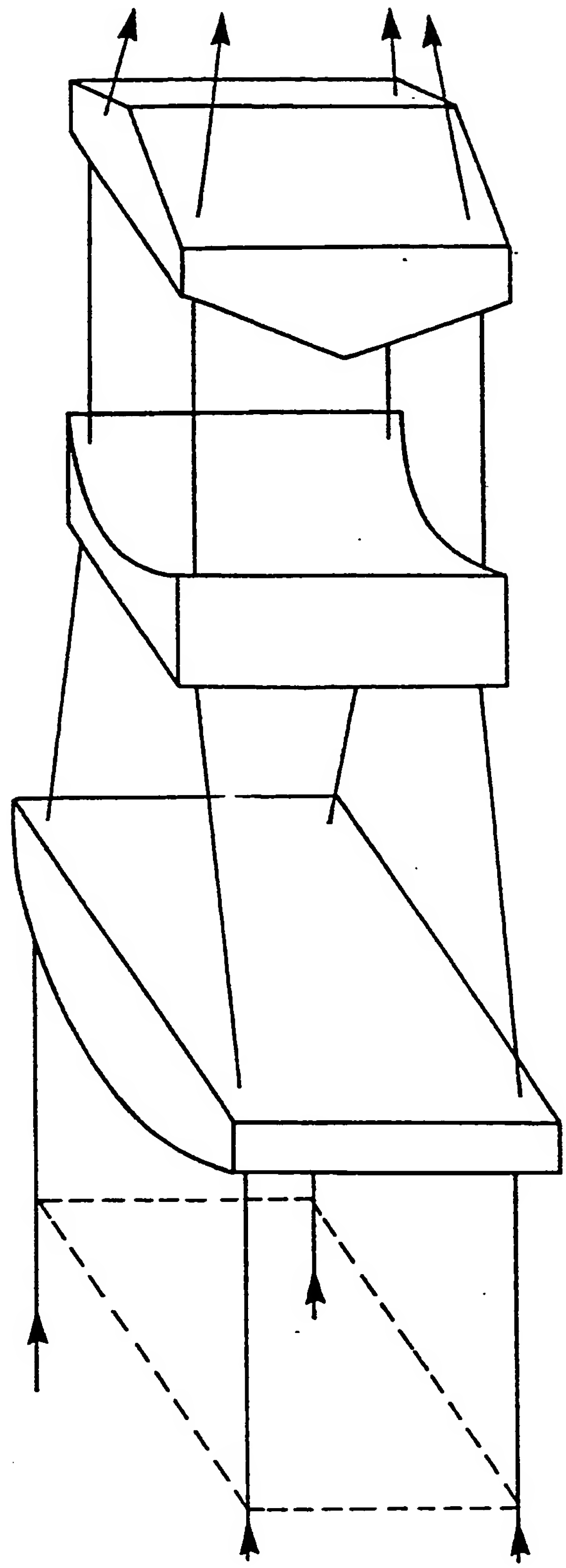

FIGURE 3(b)

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Excimer Laser Beam Homogenizer System

This invention relates to optical systems consisting of transmissive elements which are used to efficiently convert the non-uniform output beams from pulsed UV excimer lasers into uniform flat top beam profiles of arbitary size.

UV excimer laser systems excited by pulsed transverse electric discharge techniques produce output beams which are usually rectangular in shape and have very non-uniform intensity distributions. Depending on laser model and gas mix used, near field distributions are quasi-gaussian with 6 to 12mm half power widths in the direction perpendicular to the discharge and flat topped with gaussian like edge fall off with 20 to 30mm half power width in the direction parallel to the discharge.

Such non-uniform beam distributions and rectangular shapes are unsatisfactory for many excimer laser applications such as photolithography, laser etching and machining of polymers and other materials, surface doping and annealing of semiconductors and laser assisted deposition of metals and compounds.

Various techniques have been proposed in the past to make non uniform laser beams more uniform using both transmissive and reflective optical devices. Reflective optical integrators using a large number of mirror segments have been used to overlap sections of large CO_2 laser [1] and excimer laser [2] beams at a given plane. Mirror beam folding methods [3] have been used with cylindrical lenses to make excimer laser beams more uniform but in one plane only. Special aspheric and spherical lens systems [4,5] have been designed to

redistribute the energy distribution in circularly symmetric laser beams to make the central region more uniform. Wedged prisms have been used [6,7] to overlap sections of circular beams with gaussian distributions at a given plane to achieve better uniformity.

All these systems suffer from the disadvantage that they do not deal adequately with the special case of the beams from excimer lasers which are not circularly symmetric. In addition they are generally complex and not highly efficient in terms of the degree to which they transfer the full energy from the laser output into a region of high uniformity.

The invention described here is specially designed to deal with the rectangular shaped beams emitted by excimer lasers which have different non unifrom distributions in 2 orthogonal planes. The system uses transmissive optical elements only to redistribute the beam energy in these two directions to produce a uniform region of arbitary size with very high efficiency.

The basic concept of the device is illustrated in figure 1. This shows how a bi-prism (1) made from high quality fused silica or other material which transmits radiation down to 190nm can be placed in the beam from an excimer laser (2) to transform a non uniform distribution in one dimension into a highly uniform distribution. The apex of the bi-prism (1) is placed in the centre of the input beam which has a width (d) between ½ power points in order to divide it into 2 exactly equal parts. The 2 beams produced are caused to cross through each other at an angle (α) dictated by the angle of the faces of the bi-prism. A highly uniform beam (3) is produced at a plane (4) at a distance D where the two beams have separated such that the ½ power points are superimposed. A relation exists between the input beam ½ power width (d), bi-prism convergence angle (α) and distance D, namely:

$$\alpha = d / D$$

The scheme shown in figure 1 produces uniformity in one dimension only and hence it is necessary to use 2 bi-prisms with apexes orientated at 90° to each other to achieve full uniformity in 2 dimensions. Figure 2 illustrates three of the ways in which it is possible to make such double bi-prisms using either one or two components.

Excimer lasers usually have rectangular output beams with typical dimensions (d_1 and d_2) 2 to 3 times greater in one plane than the other. Consequently it is necessary to have different convergence angles (α_1, α_2) for the two sections of the double bi-prism in order to cause exact superposition of the ½ power points in both directions at the same distance from the prism

ie $\quad \alpha_1 = d_1 / D \qquad \alpha_2 = d_2 / D$

The distance (D) from the bi-prism at which uniformity is achieved can be varied by varying the angle of convergence (α_1, α_2) of the bi-prism faces.

The systems illustrated in figure 2 transform a non uniform rectangular beam into a uniform one that is also rectangular. For many applications however, it is desirable to produce square output beams and the systems illustrated in figure 3 show how this can be readily achieved using cylindrical lenses made of fused silica or other suitable transmissive material.

In figure 3(a) the smaller dimension of the input beam is expanded to make it equal to the larger dimension before recollimation and entry into the double bi-prism. In figure 3(b) the larger dimension of the beam is reduced to make it equal to the smaller before recollimation and entry to the bi-prism. In both of these cases, where the input beam to the

double bi-prism is square it is usual that the bi-prism angles ($\alpha 1$ and $\alpha 2$) will be the same.

Several methods can be used to further change the size of the output beam produced. The output plane with high uniformity can be imaged onto any other plane using a suitable lens system. In doing so the size can be reduced or increased to any value.

Alternatively, a simple converging or diverging lens of focal length f may be placed immediately adjacent to the double bi-prism. In the case of a converging lens, the beam size is reduced by a factor M and the distance to the plane of uniformity reduced from D to x. The following simple relation can be used to determine x and M:

$$x = \frac{f\,D}{f + D} \qquad M = \frac{f}{f + D}$$

In the case of a diverging lens, the beam size is increased and the distance to the plane of uniformity correspondingly increased.

To avoid loss of laser beam energy caused by reflections from the various surfaces of the lenses and bi-prisms used in these devices, it is advisable to coat all surfaces with some type of anti reflection coating. This may be a conventional vacuum deposited dielectric multilayer film stack but such coatings do not operate over a wide range of wavelengths in the UV region and are limited to low values ($<1 J/cm^2$)in laser fluence they can withstand before damage occurs.

For the device proposed her, a better solution is to use colloidal silica spun on anti-reflection coatings to avoid reflection losses. Such coatings can be readily applied, have high damage levels ($>1 J/cm^2$) and can be made to have low

reflectivities over a wide range of UV wavelengths (eg 193 to 308nm).

Specific embodiments of this invention are as follows:

The system illustrated in figure 3(a) can be used to convert the non uniform output from an excimer laser producing a rectangular beam of approximately 20mm x 10mm dimensions at a wavelength of 193nm into a uniform square beam of 20mm x 20mm size at a distance of 0.5 to 1m from the output. A mask which defines the structure to be processed can be placed in this plane. Using a lens an image of the uniformly illuminated pattern defined by the mask can then be projected onto the workpiece for processing.

In another application of this device, the system shown in figure 3(b) can be used to convert the output of an excimer laser with a beam of 25mm x 10mm operating at 248 or 308nm into a uniform square of 10mm x 10mm size at a distance of 0.5 to 1m. Using a lens, this area can be relayed into another plane for the purpose of machining and marking of plastics and other materials.

The dimensions of beam sizes and distances in these applications are merely illustrative. The range of input and output beam sizes and distances possible are very wide and not restricted in any way.

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CLAIMS

1) An optical homogenizer system consisting of a single biprism made of fused silica placed in the beam from an ultra-violet excimer laser to efficiently transform the non uniform beam into one having a much higher degree of uniformity in one dimension at a particular plane situated some distance from the prism.

2) An optical homogenizer system as in Claim (1) where two separate biprisms with angles at 90^{o} to each other are used to make the beam more uniform to both dimensions.

3) An optical homogenizer system as in Claim (2) where a single double biprism element is used instead of two separate single biprisms.

4) An optical homogenizer system as in any preceding claim where a pair of cylinder lenses are placed before the prism or prisms to change the beam shape from rectangular to square.

5) An optical homogenizer system as in any preceding claim where a spherical lens is placed after the prisms to make the output larger or smaller.

6) An optical homogenizer system as in any preceding claim where a spherical lens is placed after the plane of uniformity and is used to image the plane to another plane with increase or decrease in size.

7) An optical homogenizer system as in any preceding claim where some or all of the components are coated with a spun on layer of colloidal silica to reduce optical reflection losses.

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